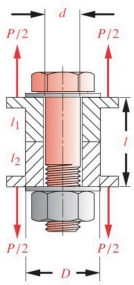
Ex7) Preloaded Bolt for Static Load

Consider $\frac{5}{16} - 18\ \text{UNC} - 2\text{A} \times 2\frac{1}{2}$ steel bolt of SAE grade 5.2 preloaded with 90% of proof strength. $P = 2000$ lb, $D = 1$-in, $l = 2$-in, $E_b = E_m = 30$ Mpsi. Find N_y and N_{sep}, its safety factors against yielding and separation.



$S_p = 85$ kpsi.

Threaded cross-section: $A_t = \frac{\pi}{4}\left(\frac{d_p + d_r}{2}\right)^2$

$$= \frac{\pi}{4}\left(\frac{d - \frac{0.649519}{N} + d - \frac{1.299038}{N}}{2}\right)^2$$

$$= 0.052431\ \text{in}^2$$

Pre-load $F_i = 0.9 S_p A_t = 0.9 \times 85 \times 10^3 \times 0.052431 = 4011$ lb

Stiffness of the bolt, $l_{thd} = 2d + 0.25 = 2 \times 0.3125 + 0.25 = 0.875$ in

$l_s = l_{bolt} - l_{thd} = 2.5 - 0.875 = 1.625$ in

$\Rightarrow l_{thd} = l - l_s = 2 - 1.625 = 0.375$ in

So, $k_b = \frac{A_t A_b}{A_b l_t + A_t l_s} E_b = \frac{0.052431 \times \left(\frac{0.3125}{2}\right)^2 \pi}{\left(\frac{0.3125}{2}\right)^2 \pi \times 0.375 + 0.052431 \times 1.625} \times 30 \times 10^6 = 1.059 \times 10^6$ lb/in

Similarly, the material stiffness

$$k_m = \frac{A_m E_m}{l} = \left(\pi\left(\frac{D}{2}\right)^2 - \pi\left(\frac{d}{2}\right)^2\right)\frac{E_m}{l} = 1.063 \times 10^7\ \text{lb/in}$$

Joint constant $C = \frac{k_b}{k_b + k_m} = 0.09056$

Portion of P for bolt and material

$P_b = CP = 0.09056 \times 2000 = 181$ lb

$P_m = (1-C)P = 1819$ lb

Resulting loads $F_b = F_i + P_b = 4011 + 181 = 4192$ lb

$F_m = F_i + P_m = 4011 - 1819 = 2192$ lb

The max tensile stress on the bolt $\sigma_b = \frac{F_b}{A_t} = 79953$ psi

Safety factor for yielding $N_y = \frac{S_y}{\sigma_b} = \frac{92000}{79953} = \boxed{1.15}$

P_o (joint separation load) $= \frac{F_i}{1-C} = \frac{4011}{1-0.09066} = 4410$ lb

Safety factor against separation

$N_{sep} = \frac{P_o}{P} = \frac{4410}{2000} = \boxed{2.2}$

Load factor (overload capacity before reaching S_p)

$N_L = \frac{S_p A_t - F_i}{CP} = \frac{85 \times 10^3 \times 0.052431 - 4011}{0.09058 \times 2000} = 2.46$